Back to the Future in the Strait of Georgia

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Abstract
Modern industrial fishing has changed the trophic structure of marine ecosystems. The phenomenon of fishing down the food web, catching all the high-trophic level table fish then gearing up to go after their prey, has been well documented at global and national level. The South China Sea is a particularly advanced example where large fish are gone, but fishers still make a living catching small fish as feed for the agriculture and aquaculture industries. Depleted systems provide fewer benefits, and increase pressure for alternative sources of wealth and livelihood such as oil and gas and salmon farming. Back to the Future (BTF) brings scientists, fishers, first Nations and other sources of information together to build computer models of past and present ecosystem states. Collaboration on the reconstruction of past abundance contributes to a greater collective understanding of ecosystem structure and function. Comparison of the ecological and social as well as economic benefits of rebuilding facilitates the setting of restoration goals that relate to productive potential rather than present scarcity. The paper draws on the first BTF project in the Strait of Georgia and current work in northern BC.

Introduction
Shortly after the launch of the 1968 Davis Plan, Department of Fisheries and Oceans (DFO) Minister Jack Davis compared the fishery to a copper mine, in which the best ore is taken first before the miner turns to progressively larger volumes of lower grade ore until the mine is exhausted. According to the North Island Gazette, “Mr. Davis then turned to the sea and explained that life there is built on the same type of pyramid, at the top is the whale and below it such species as the salmon and the tuna. As the base broadens out it contains fish successively smaller but in greater number until, at the bottom, is the limitless mass of plankton which supports the whole pyramid.” The whale, the Minister said, has been virtually wiped out and the tuna and the salmon will be the next to go as man works his way down the pyramid to the plankton (Meggs 1991).

Since Minister Davis demonstrated his remarkable grasp of marine ecosystems and human behaviour, the phenomenon of fishing down marine food webs has been documented globally (Pauly *et al.* 1998) and for Canadian waters (Pauly *et al*. 2001). First Nations, fishers, scientists, managers, conservationists and the general public are concerned about the depletion and possible disappearance of entire species. This was brought forcibly to the attention of Canadians by the collapse of the east coast cod fishery, one of the great natural resources of the planet, and the closure of the entire Fraser River salmon fishery in 2000. What Minister Davis did not foresee was the next step, where high-level decision makers evaluate the tradeoffs between conservation and restoration of depleted marine ecosystems and earnings from offshore mining, oil and gas and farmed salmon. This dichotomy is now firmly entrenched in Canada’s Ocean strategy, where ‘ecosystem management’ is a mere pawn in the ‘integrated management’ game.

Back to the Future (BTF) is an ecosystem restoration agenda. The need comes from the impact of modern industrial fishing on abundance, biodiversity and trophic structure of aquatic ecosystems. Three ratchet-like processes contribute to this effect (Pitcher 2001). As large fish such as the Atlantic cod are fished out, fleets gear up to catch their prey, witness large and lucrative shrimp and crab fisheries now in place on the east coast. Canadian west coast analogues are the disappearance of halibut from the Strait of Georgia (Figure 1) and depletion of lingcod and rockfish. A parallel ‘economic ratchet’ drives increased investment in vessels, fuel and technology to catch the last of the big fish and gear up for the next fishery. A third ‘cognitive ratchet’ operates because fishers and scientists alike tend to see what was there at the start of their careers as what there ‘ought to be’. The perception of productive potential thus ratchets down with succeeding generations (Pauly 1995). Restoration, not ‘sustainability’ is the appropriate strategy for depleted systems or stocks such as Georgia Strait lingcod and rockfish. BTF sets out to determine what it would be possible to restore and what that would be worth in ecological and social as well as economic value.

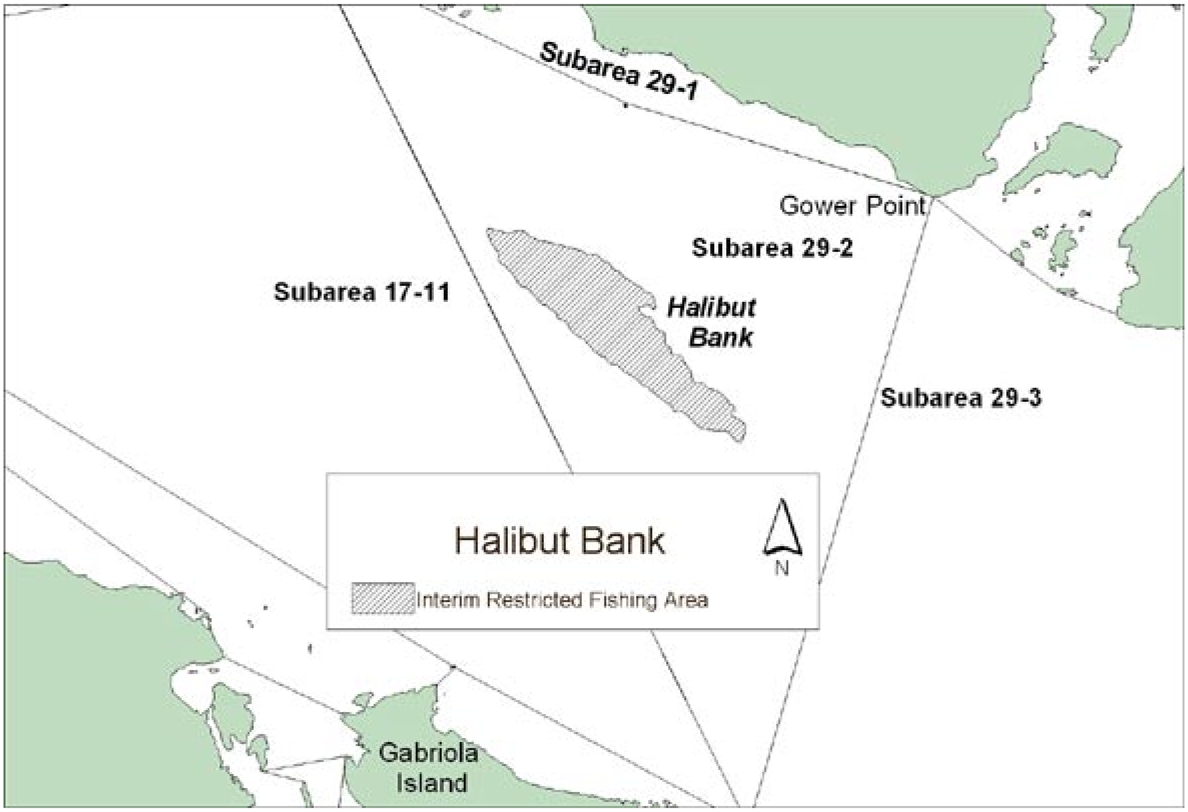

Figure 1. Halibut Bank in the Strait of Georgia, only the name remains. Map courtesy of DFO.

Are we trying to go back in time?

Permanent and local extinctions are frequently cited as factors that negate any predictive value of 'going back in time.' We beg to differ. BTF is not trying to restore Steller's sea cow, however, the structure of a BC ecosystem with sea cows was explored in the first BTF project (Pitcher 1998a) as a matter of scientific interest. Reversal of local extinctions has enormous potential impact. Sea otters do affect ecosystem structure. In their absence, sea urchins graze unrestrained on giant kelp (*Macrocystis spp.*), creating large, relatively lifeless 'urchin barrens'. The return of sea otters to BC waters would increase kelp forests and associated species, but reduce abundance of some shellfish and invertebrate species. 'Future' BTF scenarios would therefore include sea otters, but not, alas, the sea cow.

Changes in oceanic regime are also cited as negating any predictive value of BTF. Climate is a powerful driver of ocean productivity. A time series of tree growth and fish catch in the eastern Atlantic shows a very powerful correspondence (Figure 2). Figure 3 shows the close relationship between salmon catch and temperature anomalies in the N. Pacific (Klyashtorin and Smirnov 1995). Fisheries management must take climate into account. However, the real effects of climate should not blind us to the immediate potential of fisheries to drive stocks to extinction. We need to focus on catch as the one variable we can control. There is past and present evidence to support this. North Sea stocks bounced back after World War Two (Froese and Pauly 2003). The closure of Georges Bank on the east coast of the US has enabled the recovery of groundfish and invertebrate stocks (Pamela Mace, *pers. comm*.).

Global warming might force sockeye salmon to retreat to the Bering Sea (Welch *et al*. 1998) and replace herring as the dominant forage species with sardines and anchovies (McFarlane and Beamish 1999). The El Nin o / Southern Oscillation and Pacific Decadal Oscillation affect the relative abundance of herring and anchovy (Baumgartner *et al.* 1992; Chavez *et al*. 2003). Past BC ecosystems also supported bluefin tuna as recorded in the oral history of the Nuu-Chah-Nulth Nation on the west coast of Vancouver Island (Haggan 2000) and archaeological evidence (Crockford 1994 and 1997). The Tsimshian language has a word for hammerhead shark (Watkinson 1999), indicating that past ecosystems can provide insight into what the future might hold. A 12,000 year archaeological sequence from a cave at Nerja, Spain shows a change from Mediterranean to Atlantic species and back (Morales *et al.* 1994). We know that industrial fishing has reduced the number of top predators in the North Atlantic by a factor of 9 since 1900 (Christensen *et al*. 2003). In May 2003, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) listed two populations of Atlantic cod as 'endangered' (facing imminent extirpation or extinction) and one as 'threatened' (likely to become endangered if limiting factors are not reversed) www.cosewic.gc.ca.

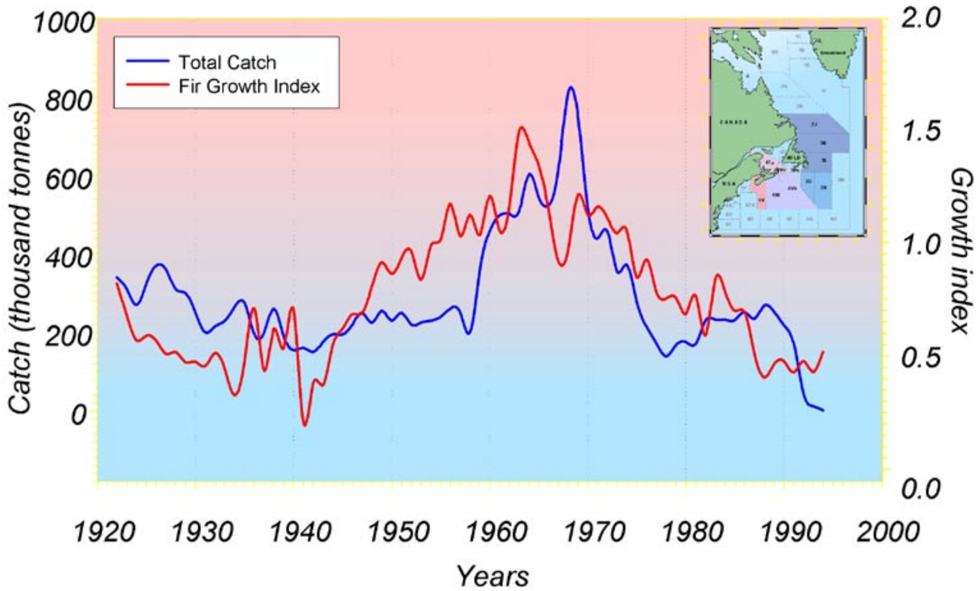

Figure 2. Catch vs. tree growth in the North Atlantic, unpublished data from Alexei Smirnov. (*Pers comm.* Eliott Burden, Memorial University, St. Johns.)

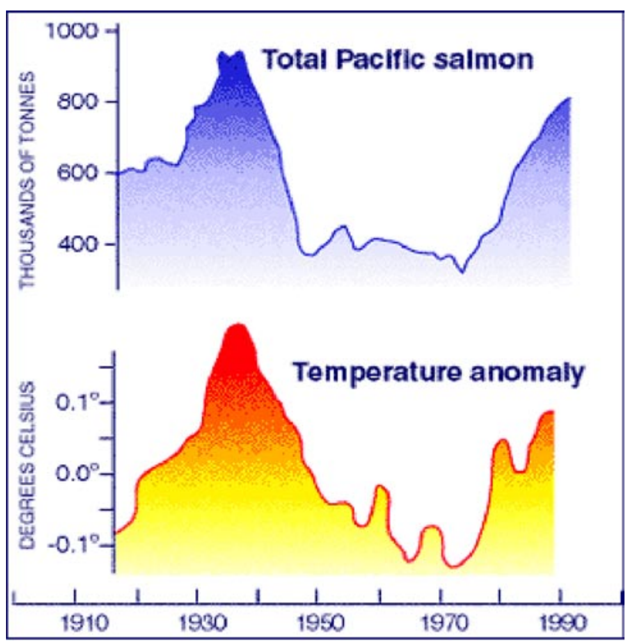

Figure 3. Pacific salmon catch and temperature anomaly (Klyashtorin & Smirnov 1995) http://whyfiles.org/139overfishing/2.html.

Fishing down the food web is also taking place in the Mediterranean (Briand 2000). Hence, both Atlantic and Mediterranean systems represented in the Nerja sequence would have a different trophic structure than those of today. From this we conclude that the past can provide valuable insight into the trophic structure and species composition of future ecosystems, and serve as a useful benchmark for restoration efforts, even with climate change.

The separation of the effects of climate from those of fishing is an important current area of ecosystem model development. Phytoplankton production anomalies predicted by Ecosim models of the BC coast from 1950 to 2001 exhibit strong correlations with upwelling indices and weaker correlations with long-term cycles such as the Pacific Decadal Oscillation and the Southern Oscillation Index. The model uses time-series data for fisheries mortality, biomass, yield and total mortality for halibut, sablefish, herring, chinook and coho salmon, eulachon, krill, and seals as reference points and then generates a primary production time series that minimizes the difference between predicted and reference values (Dave Preikshot *pers comm.*). This goodness of fit measure is a weighted sum of squared deviations of log biomasses from log predicted biomasses (Christensen *et al*. 2000).

Information sources and data-sharing in BTF

The examples cited introduce the important principle of cross validation of information sources. The scientific world ignored the Nuu-Chah-Nulth information until archaeological data made them sit up and listen. Information sources for past ecosystem models like the Strait of Georgia 100 and 500 years ago include scientific data, history and archives, traditional and local ecological knowledge, archaeological evidence and past climate signatures (Wallace 1998). Ecosystem modeling assigns different degrees of confidence to data depending on whether it comes from a reliable source e.g. detailed scientific survey, or is cross-validated by one or more other sources.

Scientists and managers agree that there is a vast amount of information in the traditional ecological knowledge of First Nations and the local knowledge of permanent fishing communities (T/LEK), but have had great difficulty in coming to grips with its application to fisheries management. T/LEK deals with ecosystem connections and with many species and their relationship to habitat, seasons, weather and other factors (Haggan 1996). It is anchored to place, hence operates at a smaller spatial scale than the highly quantitative methods used for today's wide-ranging industrial fisheries (Newell and Ommer 1999). It is anecdotal and fuzzy compared to the crisp reports, tables and graphs that fisheries scientists are taught to produce. Single species science is a spotlight on a star performer; T/LEK illuminates the entire stage, including the supporting cast of characters. Bringing these sources of information together requires cooperation between natural and social scientists and fishing communities (Berkes *et al*. 1998; Felt *et al*. 1997; Haggan *et al*. *in* press; Hutchings *et al*. 1997; Johannes 1981; Johannes 2000; Neis 1992; Neis *et al.* 1999). Ecosystem science has to be able to integrate information from different sources and across spatial scales.

Participatory elements

Today's fishery problems cannot be solved by government management, even if DFO were not suffering from severe budgetary cutbacks. There has been much talk about the need for a 'new consensus' in the Pacific fishery. This suggests that there was an 'old' consensus but there is no evidence of any consensus in the glory days of the BC commercial fishery other than 'plenty of fish in the sea'. The Department of Marine and Fisheries, later DFO, came into being as the realization dawned that Pacific fisheries were finite. Industry and management had a tacit agreement to abide by a set of rules. It's not the number of police that keeps us alive on our streets and highways; it's the agreement between road users to follow a set of rules (Haggan 1998). Significant social stigma attach to those who break the rules, as witnessed by the recent conviction of the Premier of BC for drunk driving and a spate of adverse publicity for street racing. There is no such agreement in today's Pacific fishery.

Scarcity, not enough fish to go round, is the main obstacle to consensus. The situation is complicated by an expanded set of players that includes U.S. hardball tactics in frequent salmon wars, conservation pressure from Non-government organizations (ENGOs), a growing share for the politically savvy and powerful sport fishery and the re-emergence of First Nations ancient rights quarterbacked by the Constitution of Canada and Supreme Court decisions. The participatory element of BTF is designed to increase awareness of the opportunity for restoration and harness the information of those who spend their lives on the water to devise solutions. Key elements are respect for different traditions and systems of knowledge, agreement to share information to increase understanding and develop solutions and a commitment to share the benefits of restoration. The university has a key role in providing a neutral forum and acting as an honest broker of information in a polarized environment where distrust of the source can make even the best information useless (Haggan 1998 and 2000).

The toolkit

The tools that enable BTF participants to integrate information from different sources are Ecopath (Christensen and Pauly 1992), Ecosim (Walters *et al*. 1997) and Ecospace (Walters *et al*. 1998). Methodology for the use and cross-validation of presence/absence and relative abundance information from multiple sources is described in Pitcher (1998b). Recent model developments are summarized in Christensen and Walters (*In review*). Collaboration between scientists, fishers, managers and others in building models of present and past ecosystems enhances understanding of the system as a whole. This is achieved in three stages. Preliminary model construction builds collective understanding amongst the scientific community; experts have to standardize their data and construct a model that satisfies the Ecopath mass-balance constraint that abundance of any group is constrained by the availability of prey. This is a very different model from the 'classic' international conference attended by experts on one area such as plankton or seabirds. In stage two, models are challenged and verified with maritime community information on presence, absence, species association, seasonality, trends, etc. Stage two is sometimes perceived as 'community workshops,' but goes far beyond that to include research by graduate students and community research assistants, archaeological and historical investigation and further collaboration within the scientific community. In stage three, scientists, maritime community, managers and decision-makers use the model they have bought into to compare the ecological and social as well as economic outcomes of different courses of action. Recent developments include the ability to include benefits to future as well as present generations (Sumaila 2001; Sumaila *et al*. 2001). Research is ongoing on ways to include marine ecosystem services in the way that Costanza *et al*. (1997) estimated the annual value of the Earth's ecosystem services at $US 33 trillion.

In summary, the collective understanding of ecosystems achieved by contributing to models builds social capital in terms of ownership and trust in the process. The university plays an important role as neutral forum and honest broker of information. Collaboration on model construction and participatory exploration of options is a significant advance on bilateral consultations. It is also qualitatively different past forums where experts have presented their models to stakeholders.

Progress and research questions

Since the inaugural Georgia Strait project (Pauly *et al.* 1998), BTF methodology development shifted to northern BC, not for any want of interest in local waters, but because further funding could not be found. The northern BC work is supported by Coasts Under Stress (www.coastsundestress.ca), a project conceived to explore the effects of changes in society and in patterns of research harvesting on ecosystem and coastal community health. The end goal is to develop local, regional and national policies that will ensure the survival of coastal communities into the far future. Models constructed with community input include the 1750s, prior to European settlement; 1900s, before trawling in northern BC; 1950s, heyday of the salmon fishery; and present day (Ainsworth *et al.* 2002). Traditional and local knowledge was gathered through interviews and one workshop was held in Prince Rupert to explore different futures and fishery configurations (Pitcher *et al.* 2002). Additional reports on methodology are in preparation and will be available on the UBC Fisheries Centre website www.fisheries.ubc.ca.

The forage fish question

The Strait of Georgia BTF project raised a question of forage fish abundance that has yet to receive a satisfactory answer. Although BC herring populations are relatively small compared to those in other parts of the world, present herring densities (g/m^2) in BC and Alaska are among the highest in the world (Hay and McCarter 1997). Hence, the present herring population in the Strait of Georgia is probably as high or higher than 100 years ago (Doug Hay pers. comm.). Certainly, herring biomass in the Strait of Georgia in 2002 and 2003 is higher than it has been for a long time (Schwiegert 2002). The problem is that between 200 and 600 humpback whales were harvested round the turn of the century (Winship 1998). Other things being equal, there must have been enough herring for the humpbacks as well as other predators.

Should we then be surprised that 2003 herring abundance is hailed as the highest in living memory? The whales are gone, lingcod and rockfish are severely depleted, chinook and coho salmon populations are low, and so what is left to eat them? Seals are an obvious culprit. Olesiuk (1999) suggests that the current harbour seal population of 37,300 (range 28,200 - 46,300), is close to historically high levels. Using a seal population of 37,300 (range 28,200 to 46,300) (Olesiuk 1999) and annual herring consumption of 200 kg (range 130 – 370 kg) per seal (Olesiuk 1993) we derive a total annual consumption of 10,300 tonnes (range 3,700 to 17,000t), significant, but not a huge bite out of the 2002 biomass estimate of 135,000t (Schwiegert 2002). The issue of the density of forage fish it would take to support the very high number of top predators thought to occur in unfished ecosystems is the subject of ongoing research.

Back to what future?

Techniques for modeling past systems and addressing the effects of ocean and regime and climate have been developed to the point where different future scenarios can be explored. Considerable interest has been shown in interviews and workshops. The real question is how to address the short- and medium-term costs of achieving long-term benefits. The economist's practice of discounting (standard in cost-benefit analysis) devalues the flow of future costs and benefits in order to reflect people's preference for immediate consumption and delayed payment. Benefits accrued long after the costly commitment to restoration is made, therefore, become inconsequential and cannot be used to justify the immediate expenditure.

Discounting the future works against the type of re-investment in natural capital proposed by BTF. It also runs counter to legislation requiring government to conserve and manage resources for present **and future** generations (emphasis added).

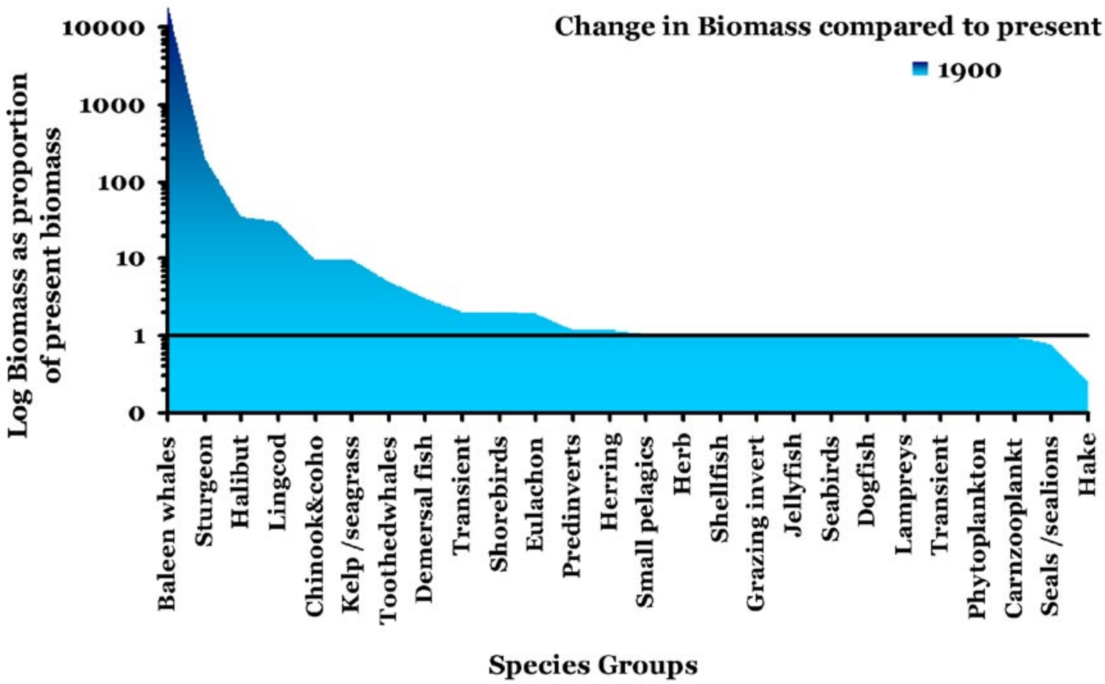

Figure 4. Change in biomass of major species in Strait of Georgia 1900 to present day.

Discounting the future is unacceptable to First Nations who take a long view, articulated in the Six Nations' ethic of '7th Generational thinking' (http://www.iisd.org/7thgen/environment.htm; Clarkson *et al*. 1992) and fishing communities along the coast who would like to see their children and grandchildren enjoy the opportunities that existed in their or their parent's lifetime. Figure 4 shows the percentage change in biomass of major species in the Strait of Georgia over the last 100 years. This shows clearly that the current generation is having a raw deal with respect to ecosystem values. The outlook for future generations is even more bleak.

Table 1. Adapted from Sumaila *et al*. (2000). Compares the value of major species in the Strait of Georgia 100 years ago with the present-day. Column 1 is a strait economic comparison based on landed price minus harvesting cost. Column 2 begins to include ecological value by assigning fish remaining in the system 10% of the value of those caught. Column 3 adds social value by including the dollar value to future generations. While this is far from capturing all the social and ecological values, the increase is highly significant.

	Strait of Georgia Benefits for 20-yr horizon ($1000/Km^{-2})		
Model Period	Economic	EE	ESE
1900	857	14,154	20,923
2000	334	5,170	6,548
(Past/Present)	256%	274%	320%

Table 1: Valuation of present day Strait of Georgia compared with 100 years ago. Ecological Economic (EE) adds value of fish left in the water; ESE adds value to future generations.

Ainsworth and Sumaila (in press), found that under conventional discounting, it was economically 'rational' to deplete Canada's northern cod, but that application of intergenerational discounting from 1985 on, would have ensured their long-term survival, even accounting for management error as described by Walters and Maguire (1995).

The BTF philosophy is that the Strait of Georgia and other marine ecosystems should be valued according to their productive potential, as determined by the flow of benefits to future as well as present generations. This requires an increase in our collective understanding of ecosystem structure and function, or a new 'Cognitive Map', of where we might get to by harnessing the wit and wisdom of the scientific and maritime community to the challenge of rebuilding (Pitcher and Haggan *in press*). It also requires a very different approach to the valuation of future benefits.

The world's oceans cover 70% of the planet and provides unseen but vital services to all life on earth. Marine ecosystems are our common human heritage. Their fisheries, scenic, cultural and other attributes have sustained human communities for thousands of years and have the potential to bring sustenance, wealth and joy to future generations. There is growing acceptance that living creatures have a right to exist, captured in the concept of 'ecosystem justice' (Brunk and Dunham 2000) and that their survival cannot be assured by their market value (Ainsworth and Sumaila in press; Sumaila and Bawumia 2000). For these reasons, the health of marine ecosystems should be the primary consideration in the decision whether to proceed with oil and gas, offshore mining, salmon farming and other activities such as effluent disposal which are more lucrative and/or convenient in the short term, but may foreclose options for future generations. This is not an argument against development that coastal communities desperately need. It is the rationale for saying that marine ecosystem values must be the primary consideration in development planning, not a pawn to the realpolitik of $100 billion in oil and gas revenue in northern BC, the substantial earnings from salmon farming ($US 387 million in 1999) and the anticipated doubling or tripling of production.

How does BTF measure up?

Costanza *et al*. (1998 and http://www.seaweb.org/resources/20update/ocean.html), distil six principles from a 1997 conference on "Ecological Economics and Sustainable Governance of the Oceans" in Lisbon, Portugal. The following is a self-assessment of BTF as a response:

1. Rights to use our natural resources come with a responsibility to use them efficiently, without depleting them, and in a socially fair way.

    Back to the Future addresses depletion by setting goals that relate to productive potential. Equity is achieved through involving all interests in analysis of the results of different conservation and harvest scenarios.

2. Ocean environments and resources should be managed at the spatial scales and time frames most conducive to their sustainability, crossing, if appropriate, political jurisdictions and human generations.

    Spatial scale is addressed by involving Indigenous and other local interests as well as commercial fishers and managers. Temporal scale is addressed by the reconstruction of change over long time periods and a variety of future scenarios.

3. In the face of uncertainty, environmental management decisions should err on the side of caution.

    Collaboration between scientists, stakeholders, NGOs and other interests in exploration of ecological consequences can increase collective appreciation of risk and promote agreement on a more cautious approach.

4. Given that some level of uncertainty always exists, environmental decision-makers should continuously adapt management plans as new, improved insight becomes available.

    Simulation modeling over time periods as long as 100 years allows 'adaptive management' strategies to be evaluated. The more partners and types of knowledge involved, the better the insight.

5. All costs and benefits concerning the use of natural resources should be identified and allocated and economic markets should reflect these costs and benefits.

    BTF does not yet provide full cost accounting. The addition of cultural and ecosystem service values to the valuation methodology application of intergenerational discounting to assess the tradeoffs between renewable and non-renewable resources to future generations would be a closer approach.

6. Participation of all stakeholders is vital in the formulation and successful implementation of decisions concerning environmental resources.

   The BTF approach is to involve all stakeholders including the public interest in developing a collective understanding of the status of marine ecosystems and developing solutions that are ecologically, socially and economically acceptable.

Table 2. Checklist evaluating performance of the 'Back to the Future' (BTF) process against Costanza *et al.* 's (1998)

Principles of Ocean Governance.

Ocean Governance Principle	included in BTF
1. Responsibility	Yes
2. Scale-matching	Yes
3. Precaution	Yes
4. Adaptive management	Yes
5. Full cost allocation	Partial
6. Participation	Yes

Conclusion

The logic of 'footloose' capital (Ommer 2000) is to fish out one stock and move on to another, or invest in something completely different with a higher rate of return (Clark 1973). Indeed, large corporations see it as their responsibility to seek the best rate of return for their shareholders. What is economic logic to business is insanity to First Nations and permanent fishing communities. It is probably illegal, considering the legislative requirement to manage resources for future as well as present generations.

Discounting the future drove the Atlantic cod and the Georgia Strait lingcod and rockfish to the edge of biological extinction. The same twisted logic will sacrifice already-depleted systems for the huge short-term gain from oil and gas, salmon farming, offshore aggregate mining and other opportunities.

Back to the Future and intergenerational discounting provide a way to balance the full spectrum of benefits from restored marine ecosystems against the short-term gain and long-term environmental costs of non-renewable resource development.

Canada should re-draft its 'Oceans Strategy' to conform to the 'Lisbon Principles' to ensure that the health of wild living resources and the marine environment is the paramount consideration in 'Integrated Management'.

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References

Ainsworth, C. and R. Sumaila. (2003). Intergenerational Discounting and the Conservation of Fisheries Resources: A Case Study in Canadian Atlantic Cod. (*in prep*)

Ainsworth, C., Heymans, J.J., Pitcher, T.J. and Vasconcellos, M. (2002) Ecosystem Models of Northern British Columbia for the Time Periods 2000, 1950, 1900 and 1750. Fisheries Centre Research Reports 10(4), 41pp.

Baumgartner, T.R., A. Soutar, and V. Ferreira-Bartrina. (1992). Reconstruction of the history of Pacific sardine and northern anchovy populations over the past two millennia from sediments of the Santa Barbara Basin, California. California Cooperative Fisheries Investigations Reports, v. 33: 24-40.

Berkes, Fikret and Carl Folke (eds) (1998). Linking Social and Ecological Systems: Management Practices and social mechanisms for building resilience. Cambridge University Press.

Briand, F. (ed) (2000). Fishing down the Mediterranean food webs? CIESM Workshop Series n°12: Kerkyra, Greece. 99 p.

Brunk, C., and S. Dunham (2000). Ecosystem Justice in the Canadian fisheries. Pages 9-33 in Just Fish: Ethics and Canadian Marine Fisheries (eds Coward, H., Ommer, R. & Pitcher, T. J.). ISER Books, St. Johns, Newfoundland. 304 Pages.

Chavez, F.P., J. Ryan, S.E. Lluch-Cota and M. Niquen. (2003). From anchovies to sardines and back: Multidecadal change in the Pacific Ocean. Science 299:217-221.

Christensen v. and D. Pauly. (1992). ECOPATH II - A system for balancing steady-state ecosystem models and calculating network characteristics. Ecol Modeling, 61: 169-185. [12, 15].

Christensen, V., and Walters, C. (*in review*). Ecopath with Ecosim: methods, capabilities and limitations. Ecological Modelling.

Christensen, V., C.J. Walters, and D. Pauly. (2000). Ecopath with Ecosim Version 4, Help system©.

Christensen, V., Guénette, S., J.J. Heymans, C.J. Walters, R. Watson, D. Zeller and D. Pauly. (2003). Hundred-year decline of North Atlantic predatory fishes. Fish and Fisheries 4:1-24.

Clark, C.W. (1973). "The economics of overexploitation", Science, 181, 630-634.

Clarkson, L., V. Morrissette and G. Régallet (1992). Our Responsibility to the Seventh Generation. International Institute for Sustainable Development. Winnipeg. 88p. also at: http://www.iisd.org/pdf/seventh_gen.pdf

COSEWIC Status Assessments, May 2003 http://www.cosewic.gc.ca/htmlDocuments/Detailed_Species_Assessment_e.htm

Costanza, R., F. Andrade, P. Antunes, M.van den Belt, D. Boersma, D.F. Boesch, F. Catarino, S. Hanna, K. Limburg, B. Low, M. Molitor, J.G. Pereira, S. Rayner, R. santos, J. Wilson and M. Young. (1998) Principles for Sustainable Governance of the Oceans. Science vol 281:198-199.

Costanza, Robert, Ralph d'Arge, Rudolf de Groots, Stephen Farber, Monica Grasso, Bruce Hannon, Karin Limburg, Shahid Naeem, Robert V. O'Neill, Jose Paruelo, Robert T. Raskins, Paul Sutton and Marjan van den Belt. 1997. The value of the world's ecosystem services and natural capital. Nature, vol. 387:253-260.

Crockford, Susan. (1994). New archaeological and ethnographic evidence of an extinct fishery for giant bluefin tuna on the Pacific Northwest coast of North America. Fish Exploitation in the Past. Proceedings of the 7th meeting of the ICAZ Fish Remains Working Group. Van Neer, W. (ed.) Annales du Musee Royal de l'Afrique Centrale, Sciences Zoologiques No. 274. Tervuren.

Crockford, Susan. (1997). Archeological evidence of large northern bluefin tuna in coastal waters of British Columbia and northern Washington. Fishery Bulletin 95:11-24.

Felt, Lawrence, B. Neis, B. McCay, (1997). "Co-management" in Northwest Atlantic Groundfish: Management Alternatives for Sustainable Fisheries, edited by Jim Wilson. American Fisheries Society.

Froese, R. and D. Pauly (2003). Dynamik der Überfischung. p. 288-295 *In:* J.L. Lozán, E. Rachor, K. Reise, J. Sündermann und H. von Westernhagen (Hrsg.). Warnsignale aus Nordsee und Wattenmeer - eine aktuelle Umweltbilanz. GEO, Hamburg, 448 p.

Haggan, N. (1996). Integration of Traditional Environmental Knowledge. P. 88, in Pauly and Christensen (eds.) Mass-Balance Models of North-eastern Pacific Ecosystems. UBC Fisheries Centre Research Reports, 1996, Vol. 4, #1.

Haggan, N. (1998) Reinventing the Tree: reflections on the organic growth and creative pruning of fisheries management structures. Pages 19-30 in Reinventing Fisheries Management, eds. T.J. Pitcher, P.J.B Hart and D. Pauly. London: Chapman and Hall, 435pp.

Haggan, N. (2000). Back to the Future and Creative Justice: Recalling and Restoring Forgotten Abundance in Canada's Marine Ecosystems. Pages 83-99 in, Coward, Harold, Rosemary Ommer and Tony Pitcher (Eds). 2000 Just Fish: Ethics in the Canadian Coastal Fisheries. ISER Books, St. Johns, Newfoundland.

Haggan, N., C. Brignall and L. Wood (*in press*) Putting Fishers' Knowledge to Work. Fisheries Centre Research Reports 11.

Hay, D.E. and P.B. McCarter. (1997). Continental shelf area, distribution, abundance and habitat of herring in the North Pacific. Wakefield Fisheries Symposium. Alaska Sea Grant College Program 97-01: p 559-572.

Hutchings, Jeffrey A., B. Neis and P. Ripley. (1997). The "Nature" of Cod *(Gadus morhua)*: Perceptions of Stock Structure and Cod Behaviour by Fishermen, "Experts" and Scientists from the Nineteenth Century to the Present. pp. 123-188 *In* D. Vickers (ed). Proceedings of the Marine Resources and Human Societies in the North Atlantic since 1500 Conference. ISER Press, St. John's, Newfoundland.

Johannes, R. E. (1981). *Words of the lagoon: fishing and marine lore in the Palau district of Micronesia*: Univ. Calif. Press. Berkeley.

Johannes, R.E., Freeman, M.R. and R.J. Hamilton (2000) Ignore fishers' knowledge and miss the boat, Fish and Fisheries 1: 257-271.

Klyashtorin, L. and R. Smirnov. (1995). Climate-dependent salmon and sardine stock fluctuations in the North Pacific. pp. 687-689 in Beamish, R. J. (ed.), Climate Change and Northern Fish Populations, Canadian Special Publication of Fisheries and Aquatic Sciences, 121, Ottawa, Canada.

McFarlane, G. A., & Beamish, R. J. (1999). Sardines return to British Columbia waters. In H. Freeland, W. P. Peterson, & A. Tyler: Proceedings of the 1998 Science Board Symposium on the Impacts of the 1997/98 El Niño Event on the North Pacific Ocean and its Marginal Seas (pp. 77–82). PICES Scientific Report No. 10, North Pacific Marine Science Organization, Sidney, Canada.

Meggs, Geoff. (1991). The Decline of the BC Fishery. Douglas and McIntyre, Vancouver/Toronto. 265p.

Morales, A., Rosello, E. & Canas, J.M. (1994) Cueva de Nerja (prov. Malaga): a close look at a twelve thousand year ichthyofaunal sequence from southern Spain. Pages 253- 262 in W. van Neer (ed) Fish Exploitation in the Past. Ann. Sci. Zool Mus. Roy. L'Afrique Centrale, Tervuren, Belg. 274.

Neis, B. (1992). *Fishers' Ecological Knowledge and Stock Assessment in Newfoundland*. Newfoundland Studies 8, No. 2:155-178.

Neis, B., L.F. Felt, R.L. Haedrich and D.C. Schneider. (1999). An Interdisciplinary Method for collecting and Integrating Fishers' Ecological Knowledge into Resource Management. pp. 217-238. In D. Newell and R.E. Ommer (eds). (1999). Fishing Places, Fishing People: Traditions and Issues in Canadian Small-Scale Fisheries.

Newell, D., and R.E. Ommer (eds). (1999). Fishing Places, Fishing People: Traditions and Issues in Canadian Small-Scale Fisheries. Univ. of Toronto Press. Toronto. 374p.

Olesiuk, P.F. (1993). Annual prey consumption by harbor seals (*Phoca vitulina*) in the Strait of Georgia, British Columbia. Fishery Bulletin 91:491-515.

Olesiuk, P.F. (1999). An assessment of the status of harbour seals (*Phoca vitulina*) in British Columbia. DFO Canadian Stock Assessment Secretariat Research Document 99/033 and http://www.dfo-mpo.gc.ca/csas/CSAS/English/Research_Years/1999/a99_033e.htm

Ommer, R. (2000). The ethical implications of property concepts in a fishery. Pages 117-139 in Coward, Harold, Rosemary Ommer and Tony Pitcher (Eds). 2000 Just Fish: Ethics in the Canadian Coastal Fisheries. ISER Books, St. Johns, Newfoundland.

Pauly, D, Ma. Lourdes Palomares, Rainer Froese, Pascualita Sa-a, Michael Vakily, David Preikshot and Scott Wallace (2001) Fishing down Canadian Aquatic food webs. Pages 51-62 in CJFAS 58(1).

Pauly, D. (1995). Anecdotes and the shifting baseline syndrome of fisheries. *Trends Ecol. Evol.* **10**, 430.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., and Torres, F. Jnr (1998) Fishing down marine food webs. Science 279: 860-863.

Pauly, D., T. Pitcher and D. Preikshot (eds.). (1998). Back to the Future: Reconstructing the Strait of Georgia Ecosystem. UBC Fisheries Centre Research Reports. Vol 6 #5. 100P.

Pitcher T.J. (2001) Fisheries Managed to Rebuild Ecosystems: Reconstructing the Past to Salvage The Future. Ecological Applications 11(2): 601-617.

Pitcher, T.J. (1998a) Pleistocene Pastures: Steller's Sea Cow and Sea Otters in the Strait of Georgia. Pages 49-52 in: Pauly, D., T. Pitcher and D. Preikshot (Eds.). Back to the Future: Reconstructing the Strait of Georgia Ecosystem. UBC Fisheries Centre Research Reports. Vol 6 #5. 100P.

Pitcher, T.J. (1998b) "Back To The Future": a Novel Methodology and Policy Goal in Fisheries. Pages 4-7 in Pauly, D., Pitcher, T.J. and Preikshot, D. (Eds) Back to the Future: Reconstructing the Strait of Georgia Ecosystem. Fisheries Centre Research Reports 6(5): 99pp.

Pitcher, T.J. and N. Haggan. (2003). Cognitive Maps: Cartography and Concepts for an Ecosystem-based Fisheries Policy. Pages 456-460 in Putting Fishers' Knowledge to Work. Haggan, N., C. Brignall and L. Wood (eds). UBC Fisheries Centre Research Reports 11.

Pitcher, T.J., Power, M. and L. Wood (eds) (2002). Restoring the past to salvage the future: report on a community participation workshop in Prince Rupert, BC. UBC Fisheries Centre Research Reports. 10(7) 56 pp.

Schweigert, J. (2002). Stock Assessment for British Columbia Herring in 2002 and Forecasts of the Potential Catch in 2003. DFO Canadian Science Advisory Secretariat Research Document 2002/110. Also available at: http://www.dfo-mpo.gc.ca/csas/Csas/English/Research_Years/2002/2002_110e.htm.

Sumaila, U. R. and Bawumia, M. (2000). Pages 140-153 Just Fish: Ethics and Canadian Marine Fisheries (eds Coward, H., Ommer, R. & Pitcher, T. J.). ISER Books, St. Johns, Newfoundland. 304 pages.

Sumaila, U. R., Pitcher, T. J., Haggan, N. & Jones, R. in Microbehavior and Macroresults: Proc. 10th *Biannual Conf. Int. Inst. Fish. Econ. Trade, Corvallis, Oregon, 10-14 July 2000* (eds Johnston, R. S. & Shriver, A. L.) (International Institute of Fisheries Economics & Trade, Corvallis, OR, 2001).

Sumaila, U.R. (2001) Generational cost benefit analysis for evaluating marine ecosystem restoration In: Tony Pitcher, Ussif Rashid Sumaila and Daniel Pauly. (eds) Fisheries impacts on North Atlantic ecosystems: Evaluations and Policy Exploration. Fisheries Centre Research Reports 9(5). 94 pp.

Wallace, S. 1998. Sources of Information Used to Create Past and Present Ecosystem Models of the Strait of Georgia. Pages 19-21 in Back to the Future: reconstructing the Strait of Georgia Ecosystem. Eds. T. Pitcher, D. Pauly & D. Preikshot. UBC Fisheries Centre Research Reports, Vol. 6 No. 3.

Walters, C. and Maguire, J. J., (1996). Lessons for stock assessment from the northern cod collapse. Rev. Fish Biol. Fish., 6:125-137.

Walters, C. D. Pauly and V. Christensen (1998). Ecospace: prediction of mesoscale spatial patterns in trophic relationships of exploited ecosystems, with emphasis on the impacts of marine protected areas. International Council for the Exploration of the Sea, ICES C.M. 1998/S: 4, 20 p.

Walters, C., V. Christensen and D. Pauly. (1997). Structuring dynamic models of exploited ecosystems from trophic mass-balance assessments. Reviews in Fish Biology and Fisheries 7:139-172.

Watkinson, S. (1999) An annotated list of Tsimshian (Sm'algyax) words pertaining to the Marine Ecosystem. Pages 28-38 in Haggan, N. and A. Beattie (eds) (1999) Back to the Future: Reconstructing the Hecate Strait Ecosystem. Fisheries Centre Research Reports Vol. 7, No. 3, 65pp.

Welch, D.W, Y. Ishida and K. Nagasawa (1998) Thermal limits and ocean migrations of sockeye salmon (*Oncorhynchus nerka*): long-term consequences of global warming. Can. J. Fish. Aquat. Sci. 55:937-948.

Winship, A. (1998). Pinnipeds and Cetaceans in the Strait of Georgia. Pages 57 in Back to the Future: reconstructing the Strait of Georgia Ecosystem. Eds. T. Pitcher, D. Pauly & D. Preikshot. UBC Fisheries Centre Research Reports, Vol. 6 No. 3.